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ABSTRACT

One in a series of core instructional materials for apprentices to use during the first or second years of apprentice-related subjects training, this booklet deals with sketching, drawing, and blueprint reading. The first section consists of an outline of the content and scope of the core materials as well as a self-assessment pretest. Covered in the five instructional chapters included in the booklet are lines, symbols, and lettering; scales and dimensions; types of drawing; sketching; and blueprint reading. Each chapter contains an overview; an introduction and objectives; principles, examples, and applications; additional information; and self-test exercises. Appended to the booklet are answers to the self-assessment pretest, answers to the self-test exercises, a posttest, and answers to the posttest. (MN)

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ED227291

SKETCHING, DRAWING AND BLUEPRINT READING

Apprentice Related Training Module

Eric Rice

U.S. DEPARTMENT OF EDUCATION
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Glossary

The words on this list are used in this booklet. Please review the terms and learn the definitions. The meaning of the words in the text may not be the form of the word with which you are familiar.

Words/Terms

1. *Axis* A straight line on which a body rotates.
2. *Convention* A generally accepted and practice way of doing something.
3. *Converse* Reversed in order.
4. *Extrapolate* To infer, project, extend or expand.
5. *Grid* A network of uniformly placed horizontal and vertical lines for locating points by means of coordinates.
6. *Isometric* A drawing in which the three surfaces are in proportion but presented to the viewer on an edge rather than a surface face.
7. *Oblique* A drawing where the front view is parallel to the projection plane but the other axis is neither perpendicular to nor parallel to the base.
8. *Orthographic* A drawing of a single view, taken on the flat plane or surface.
9. *Perspective* The type of drawing where objects appear as they do to your eyes with respect to distance and position.
10. *Projection* A view (drawing) of an object.
11. *Ratio* The relationship in quantity, amount or size between two or more things.
12. *Standardize* To make things conform.
13. *Vanishing Point* The point at which the lines on a perspective drawing merge into the horizon.

1. How To Use This Booklet

What Is This Series About?

Sketching, Drawing and Blueprint Reading is one of ten booklets written as core instructional materials for apprentices to use during the first or second years of apprenticeship related subjects training. Nine of the booklets are about critical subject areas for apprentices, as determined by a national group of experts on apprenticeship and training. The tenth booklet introduces the other booklets and explains how to use the materials in the instructional setting.

The materials are designed to be used with other related subjects instructional materials. They can be employed in one of two ways: (1) the materials can be used as the total instructional materials package for some trades, in subjects such as basic science, measurement, and working in organizations; or (2) they can be used as supplementary, introductory or practice materials in subjects such as basic mathematics, safety and an introduction to apprenticeship.

The booklets are written in a self-instructional, self-paced format. They can be used either in instructor-supervised or independent study arrangements. *Each booklet and each chapter is written as a distinct unit and is addressed to a single major topic.* This means that you or your instructor can select individual booklets or chapters without necessarily using every booklet or every chapter within a booklet.

The booklets emphasize application of facts, concepts and skills. Material is presented by means of written information, visual illustration and applied example. The discussion for most major topics also includes an application section that requires you as a learner to demonstrate what you are learning. In addition, each chapter contains a section entitled Self-Test Exercises that contains questions, problems and exercises for you to work through as a final application of the knowledge or skill and to show that you have mastered the materials.

The titles of the booklets in the core materials are:

1. *A Basic Core Curriculum*
2. *Introduction to Apprenticeship*
3. *Basic Mathematics*
4. *Basic Safety I*
5. *Basic Safety II*
6. *Basic Measurement*
7. *Sketching, Drawing and Blueprint Reading*
8. *Basic Physical Science*
9. *Working in Organizations*
10. *Interpersonal Skills and Communication*

What Is This Booklet About?

This book is about a language used in some form or another by almost every tradesperson and craftsworker. The language is one of pictures, drawings and sketches. The language of graphics is an especially valuable tool in manufacturing and construction because it permits description and

explanation of the size and shape of objects. Imagine how difficult it would be to describe in words alone exactly how to build (or repair) an entire house, car, computer or rocket engine. With all various parts, such manufacturing/building requires from several to several thousand drawings per complete object. Not only must every part be described, but also the entire view of the object must be presented as well as illustrations that describe and explain how the various parts fit together to enable them to work.

This booklet presents basic information about sketching, drawing and blueprint reading. The topics covered in this volume are:

1. Lines, Symbols and Notation
2. Scale and Dimensions
3. Types of Drawings
4. Sketching
5. Blueprint Reading

What Must I Do To Complete My Work In This Booklet?

Working your way through this booklet will require you to read the text, to answer the questions, to perform the exercises and to complete the pretest and posttest instruments. Expect to spend about five hours working through the materials. The only resources you need to complete your work in this booklet are: (1) a copy of the booklet; (2) a pencil or pen; and (3) about four hours of time.

The materials are written in a self-instructional, programmed format. You may work through the text, examples, and questions at your own pace and leisure. You need not complete your work in the booklet at one sitting.

Each chapter in the booklet is devoted to a single skill, competency or unit of knowledge. The general format of the chapters is similar, with the following parts:

1. A *chapter overview* containing all the necessary information you need to know in order to work through the chapter.
2. An *introduction* describing the knowledge or skill and the instructional objectives for the information.
3. *Principles, examples, and applications* presenting and explaining the content as well as offering you practice opportunities to apply the information.
4. Additional *sources of information.*
5. A *self-test exercise* for applying the information under consideration.

This booklet concludes with an appendix that contains the answers to the pretest, the self-test exercises from each chapter and the posttest.

How Much Do I Know About The Subject As I Begin?

Begin your work in *Sketching, Drawing, and Blueprint Reading* by completing the self-assessment pretest that follows. When you have completed the pretest as directed in the assessment instructions and have finished reading the other material in this introductory section, continue your work in this booklet, one chapter at a time. Begin with Chapter 2 unless the results of your self-assessment indicate that you should do otherwise.

In each chapter, do the following:

1. Read:
   - Background information
   - Steps and procedures for performing skilled activities and explanations of major points and ideas
   - Examples illustrating use of information, performance or skills, or application of material
2. Consider the questions and exercises in the text. Work the questions and check your answers.
3. When you believe that you have mastered the material, take the Self-Test at the end of the chapter.
4. Check your answers with those provided in the Appendix at the end of the booklet. If you achieve at least the minimum acceptable score, move to the next chapter. If your score is below acceptable levels, work through the chapter again.

Self-Assessment Pretest

Directions: The self-assessment will help you focus on specific strengths and limitations of your sketching, drawing and blueprint reading knowledge and skills. Select the best answer for each question and record it in the appropriate space. After you have worked through the entire pretest, score your test following the directions at the bottom of the test.

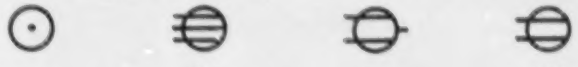
1. What is the meaning or use of the following line?

   Answer: _____

2. What is the meaning or use of the following symbol?

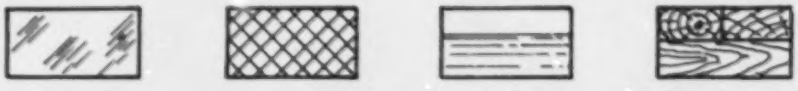
   Answer: _____

3. Circle the letter of the following symbol that represents floor outlet.



   a. b. c. d.

4. Circle the letter of the following symbol that represents sound and heat insulation.



   a. b. c. d.

5. For what purposes are civil engineer's scales usually used?

   Answer: _____

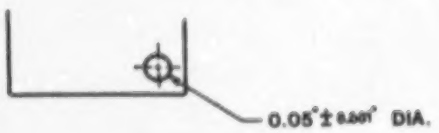
6. Define scale.

   Answer: _____

7. Dimension provides information about what elements of design?

   Answer: _____

8. On the following drawing, indicate what is expressed about tolerance.

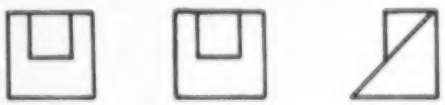


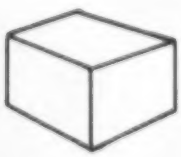
Answer: _____

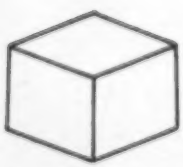
9. Circle the letter of the following item that is *not* a general convention for dimensioning.
   a. Dimension lines are solid light lines terminated by arrowheads
   b. Dimensions that are larger are written larger than other dimensions
   c. Dimensions should be no smaller than 1/8"
   d. Dimensions are usually placed so they can be read from the bottom

10. Working drawings provide information about which of the following items (check all that apply):
    a. Size and shape of object
    b. Location of component parts and features
    c. Materials specifications
    d. Fasteners, hardware, adhesives and other custom fasteners
    e. Finishing techniques and sometimes instructions

Examine the following drawings and match the type of drawing to the appropriate name:

11. _____ 

12. _____ 

13. _____ 

Possibilities:

a. oblique
b. orthographic
c. perspective
d. isometric
e. sectional
f. auxiliary

2. Lines, Symbols, And Lettering

Chapter Overview

Purpose:	To insure that each apprentice has a working knowledge of fundamental terms and conventions used in sketching, drawing and blueprint reading.
Preassessment Score:	Write in the following space the number of correct answers from Pretest questions 1-4: _____. If you answered all 4 correctly, skip to Chapter 3. If you missed one or more questions, continue to work in this chapter.
Prerequisites:	Chapter 1 of this booklet.
Resources:	Time—At least 45 minutes to completion. Materials—pencil, paper
Performance Statement:	At the conclusion of this unit you will recognize, identify and use the major conventions for symbols, sketches, and blueprint reading.
Performance Measure:	A fifteen-minute paper and pencil test to be taken after completing the entire booklet.
Standards:	To be successful, you must answer at least 70% of the Posttest items correctly.
Activities:	1. Read the text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the Self-test Exercises and Posttest.

Introduction and Objectives

Sketches, drawings and blueprints, emphasize visual rather than narrative communication. Shape, size and the location of parts of objects are the critical elements. Shape is illustrated by lines; size is indicated by dimensions; and location is marked by symbols and lettering. Each is necessary for understanding, using and sketching working drawings on the job.

Fortunately for everyone who uses drawings and blueprints, the American Standards Association (ASA) has developed and encouraged use of a single set of conventions or typical practices for lines, symbols and dimensions. Therefore, once you learn the conventions, you will be able to apply them in all situations. This chapter deals with the conventions for lines, symbols and lettering.

When you have completed your work in this unit, you will demonstrate your competence with the information in the chapter by being able to:

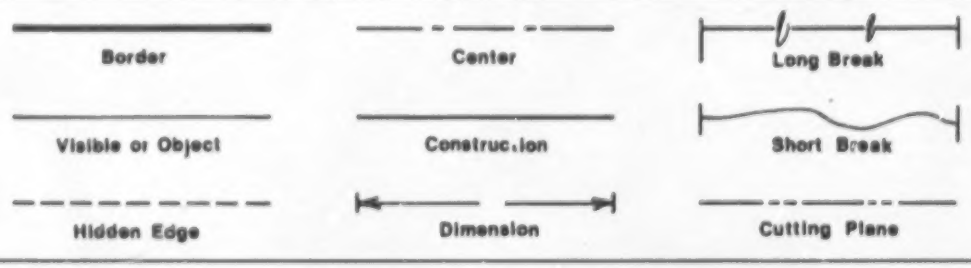
1. Recognize, identify and explain the use of line conventions in drawing;
2. Recognize, identify and explain the use of graphic symbol conventions in drawing; and
3. Recognize, identify and explain the use of lettering conventions in drawing.

Principles, Examples and Applications

Lines

Drawings illustrate the shape of objects through the use of lines. There is an alphabet of lines for drawing, each with a different meaning. For example, the lines that mark the outside of an object are called object lines. They are thick, solid, heavy, dark lines that outline the external shape of an object. Conversely, edges hidden from view are represented by a thin, uniformly broken line. The different types of lines used in job related drawings, sketches and blueprints are illustrated in Figure 1. Carefully study the lines and their suggested uses.

Figure 1. Types of Lines



Adapted From: J. R. Lindbeck and I. T. Lathrop. *General Industry, 2nd Edition.* Peoria, IL: Charles A. Bennet Co., 1977.

Without referring to the figure, identify the following types of lines:

1.

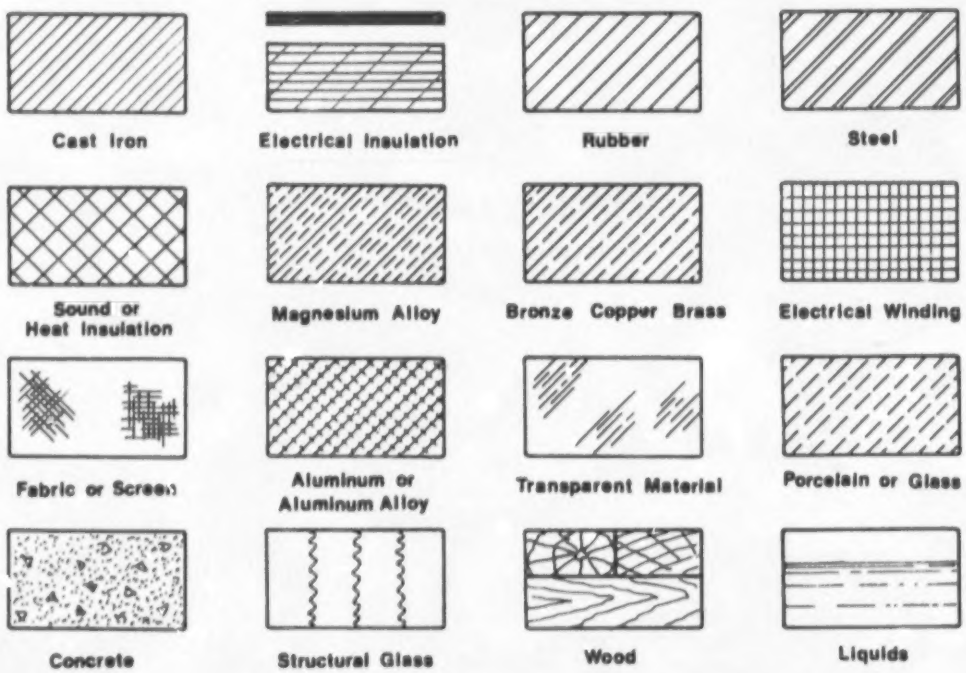
2.

Answers:
1. = Center
2. = Long break

Symbols

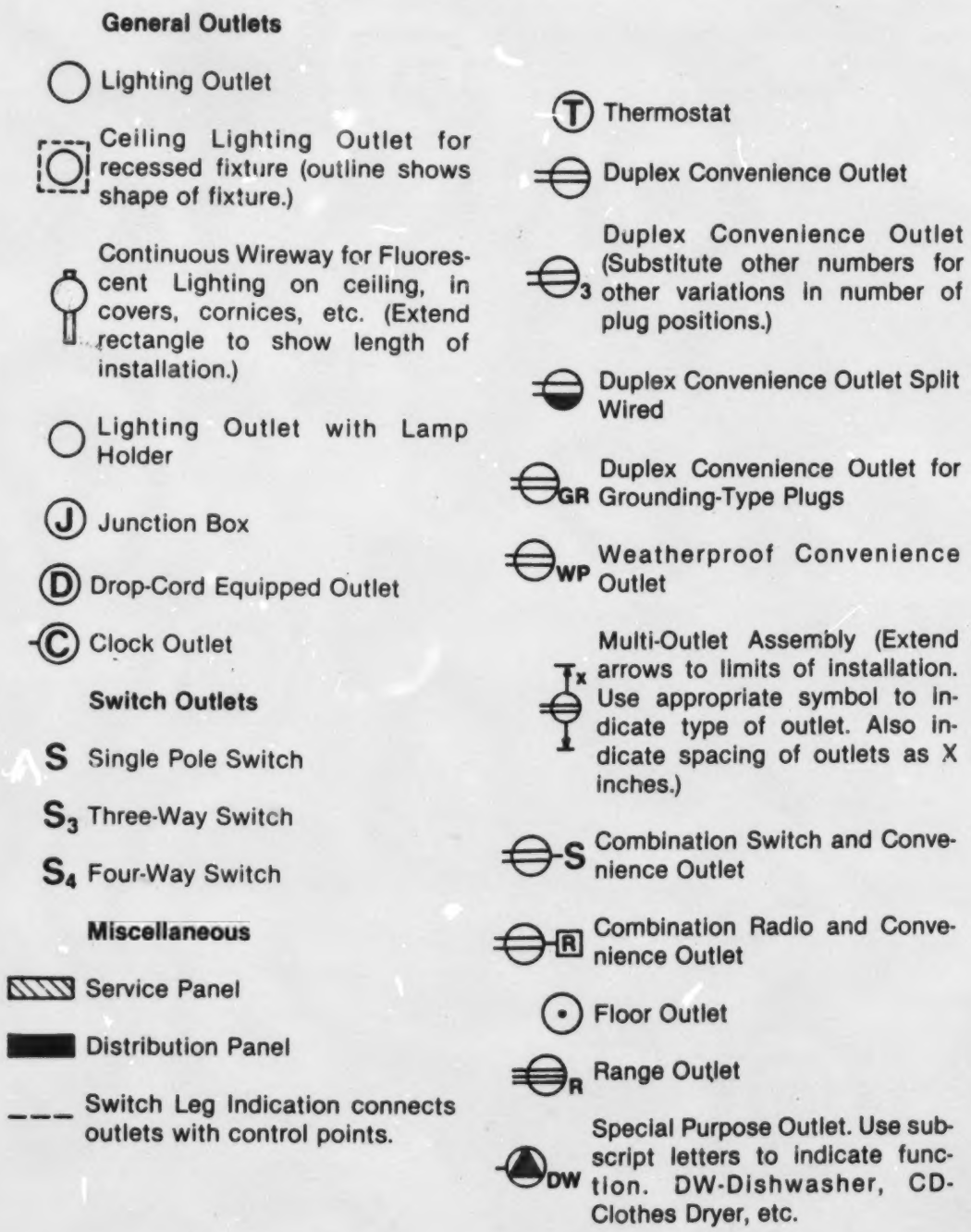
While lines are used to indicate the shape of objects, symbols are used to indicate both the location and type of items like switches or materials. For example, symbols are used to indicate the type of material to be used in constructing objects, the location of and types of fasteners and fixtures and the types of equipment. More specifically, on an electrical diagram, symbols indicate outlet, switch and box location. On a construction blueprint they indicate type of material to be used in parts of the structure while in installation and repair manuals they represent types of switches and valves. In Figure 2 are depicted basic construction materials and location symbols while Figure 3 presents fundamental electrical symbols. Note that neither of the lists is complete; only the more frequently used symbols are illustrated.

Figure 2. Basic Construction Graphic Symbols



Adapted From: J. R. Lindbeck and I. T. Lathrop. *General Industry, 2nd Edition.* Peoria, IL: Charles A. Bennet Co., 1977.

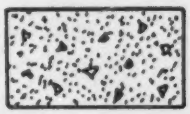
Figure 3. Basic Electrical Symbols


General Outlets
Lighting Outlet
Ceiling Lighting Outlet for recessed fixture (outline shows shape of fixture.)
Continuous Wireway for Fluorescent Lighting on ceiling, in covers, cornices, etc. (Extend rectangle to show length of installation.)
Lighting Outlet with Lamp Holder
J Junction Box
D Drop-Cord Equipped Outlet
C Clock Outlet
Switch Outlets
S Single Pole Switch
S3 Three-Way Switch
S4 Four-Way Switch
Miscellaneous
Service Panel
Distribution Panel
Switch Leg Indication connects outlets with control points.
T Thermostat
Duplex Convenience Outlet
3 Duplex Convenience Outlet (Substitute other numbers for other variations in number of plug positions.)
Duplex Convenience Outlet Split Wired
GR Duplex Convenience Outlet for Grounding-Type Plugs
WP Weatherproof Convenience Outlet
X Multi-Outlet Assembly (Extend arrows to limits of installation. Use appropriate symbol to indicate type of outlet. Also indicate spacing of outlets as X inches.)
S Combination Switch and Convenience Outlet
R Combination Radio and Convenience Outlet
Floor Outlet
R Range Outlet
DW Special Purpose Outlet. Use subscript letters to indicate function. DW-Dishwasher, CD-Clothes Dryer, etc.

Adapted From: J. R. Lindbeck and I. T. Lathrop. *General Industry, 2nd Edition.* Peoria, IL: Charles A. Bennet Co., 1977.

Without referring to the figures, answer the following questions:

1. What does this symbol mean?



Answer: _____

2. Match the symbol for type of outlet with the appropriate label.

Answer: _____

Answers:

1. = Concrete
2. = Lap outlet

Lettering

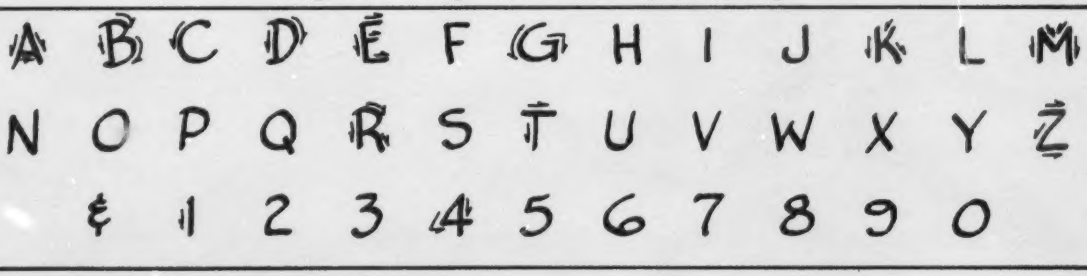
In addition to the shape and size of drawings, you also must label parts and views as well as include explanatory notes. Information such as the name of the object, building materials and types of hardware are critical. In order to include this information you must letter.

The style of lettering generally used is called "Single Stroke Gothic." It is printed such that no letter touches any other letter. Letters may be in either lower (small) case or upper (capital) case sizes although upper case letters are more frequently used. In addition, letters generally are formed using a slant of about 65° - 70°, about the normal slant for most handwriting. Additionally, the space between letters is only about a quarter as much space as is required to form the average letter. The space between words is about twice that of the average letter. Also, remember that when writing fractions, the numbers do not touch the line and the division line is located in the center of the whole number.

Numbers can be drawn either at a slant or vertically, depending upon your own preference; however, the two styles may not be mixed on the same drawing. Whether you decide to use vertical or slanted letters, do not hestiate to use guidelines to help insure uniform letter size. The most important thing to remember is that lettering must be neat and legible. Poor lettering can render a nicely-crafted drawing unusuable if the information cannot be read by a craftsworker.

Take a few minutes and study Figure 4. In this figure are illustrated each of the Single Stroke Gothic letters. The arrows indicate the general direction of the strokes for making each letter. Take your pencil and trace over the letters. Then try your hand at forming each letter on a piece of scratch paper.

Figure 4. Single Stroke Gothic Lettering



Additional Information

For additional information on lines, symbols and letters, you may choose to read:

J. R. Lindbeck and I. T. Lathrop. *General Industry, 2nd Edition.* Peoria, IL: Illinois, Charles A. Bennet Co., 1977.

J. W. Giachino and J. J. Beukema. *Everyday Sketching and Drafting, 2nd Edition.* Chicago, IL: American Technical Society, 1973.

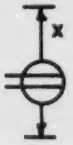
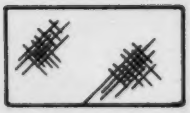
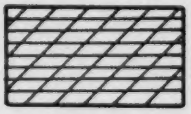
Self-test Exercises

Answer each of the following questions and compare your answers with those provided in the Appendix of this booklet.

1. Match the letter of each of the following examples of lines with the number that represents their appropriate name.

a.	——— - ——— - ———	1. Hidden
b.	- - - - - - - - - -	2. Object
c.	———————	3. Center

2. Match the letter of each of the following symbols with the number that represents the symbol's appropriate name

a.		1. Fabric or Screw
b.		2. Range Outlet
c.		3. Electric Insulation
d.		4. Multi-Outlet

3. Draw the following letters as Single Stroke Gothic letters. Indicate with arrows, the strokes you used to make the lines.

A
E
G

3. Scales and Dimensions

Chapter Overview

Purpose:	To insure that each apprentice has a working knowledge of the scale and dimension conventions used in sketching, drawing and blueprint reading so as to enable workers to read, use and make job-related working drawings.
Preassessment Score:	Write in the following space the number of correct answers from Pretest questions 5-8: _____. If you answered all 4 correctly, skip to Chapter 4. If you missed one or more questions, continue to work in this chapter.
Prerequisites:	Chapter 1 of this booklet.
Resources:	Time—At least 45 minutes to completion. Materials—pencil
Performance Statement:	At the conclusion of your work in this chapter you will recognize, identify and use the major conventions for scales and dimensions in job-related working drawings.
Performance Measure:	A fifteen-minute paper-and-pencil test to be taken after completing the entire booklet.
Standards:	To be successful, you must answer at least 70% of the Posttest items correctly.
Activities:	1. Read the text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the Self-test Exercises and Posttest.

Introduction and Objectives

Sketches, drawings and blueprints emphasize visual rather than written information; however, without some written information on a drawing, you would understand only the shape of the object. Scale, dimensions and explanatory notes are three of the types of writings found on working drawings. Scale and dimension notes explain the size of objects. Dimensions and explanatory notes provide all the information necessary to build the object. To see if you used scale, dimension and notes correctly, give your drawing to a craftsperson and see if he or she can use the drawing to build the object.

As with the conventions for lines, symbols and lettering, the American Standards Association has established a set of guidelines for scale and dimension. By learning and using these guidelines you will share a common understanding of working drawings with all other craftspersons.

In this chapter you will learn the rules, guidelines and conventions for scales and dimensions. When you have completed your work, you will demonstrate your understanding by being able to:

1. Recognize, identify and explain the use of various scale and dimension conventions; and
2. Critique and or label drawings appropriately in terms of scale and dimension.

Principles, Examples and Applications

Scale

The scale of a drawing is the ratio of the drawn object to its actual size. Scale is important because many times a sketch must be drawn smaller than the actual size of the object in order to fit the picture onto a manageable sheet of paper. A house blueprint, a wiring diagram, or a working drawing of a new car design are typical examples of working drawings that usually are scaled "down" from the actual size of the object. Conversely, drawings of small and complicated parts of many machines are drawn larger than actual size in order to emphasize required detail.

When drawing an illustration, select scale size so that (1) the drawing will fit on the paper; (2) the drawing can be used conveniently; and (3) the detail can be depicted. Remember, an appropriately scaled drawing often is of more value than a full-size drawing.

The scale used in a drawing always should be indicated on the illustration. The most frequently used scales in apprenticeable trades are the architect's scale, the mechanical engineer's scale and the civil engineer's scale. While each tool looks very similar, the scale itself is graduated differently for each instrument. The scales found on each instrument are illustrated in Figure 5.

Figure 5. Scales Found on Most Working Drawings in Apprenticeship

Architect's Scale	Mechanical Engineer's Scale	Civil Engineer's Scale
3/32 inch = 1 ft	1/8 of an inch = 1 in or 1 ft	1 inch = 1 foot or 10 ft
3/16 inch = 1 ft	1/4 of an inch = 1 in or 1 ft	1 inch = 2 feet or 20 ft
1/8 inch = 1 ft	3/8 of an inch = 1 in or 1 ft	1 inch = 3 feet or 30 ft
1/4 inch = 1 ft	1/2 of an inch = 1 in or 1 ft	1 inch = 4 feet or 40 ft
3/8 inch = 1 ft	1 = 1 ft	1 inch = 5 feet or 50 ft
3/4 inch = 1 ft	1.5 inches = 1 in or 1 ft	1 inch = 6 feet of 60 ft
1/2 inch = 1 ft	2 inches = 1 in or 1 ft	
1 inch = 1 ft	3 inches = 1 in or 1 ft	
1.5 inches = 1 ft	4 inches = 1 in or 1 ft	
3 inches = 1 ft		

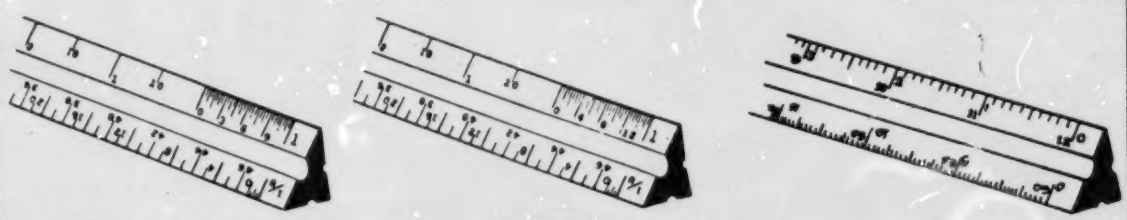
Adapted from G. E. Stephenson, *Drawing for Product Planning.* Peoria, IL: Charles A. Bennett Co., 1970.

The choice of scale is generally left to the person doing the drawing. However, regardless of scale selected, the scale on any single drawing must be consistent for the entire drawing and must be indicated (usually in the title) on the drawing.

In the building industry the architect's scale is used most frequently. House plans often are drawn to a scale of 1/4 inch equals 1 foot. In the manufacturing industry the mechanical engineer's scale is used most frequently. It is especially well suited for drawings with dimensions in fractions of inches. The civil engineer's scale is used most often to depict large distances such as those involved with road and bridge construction or the layout of an entire subdivision.

Typically-used scales for each instrument are illustrated in Figure 6.

Figure 6. Typical Scales



Architect's Scale | Mechanical Engineer's Scale | Civil Engineer's Scale

As you will note in the figure, the architect's scale and mechanical engineer's scale are very similar, the main difference is that the first is generally scaled in feet and the latter in inches. Also, the engineer's vernier scale contains 12 graduations representing inches while the mechanical vernier scale is made up of 16 graduations each representing one-sixteenth of an inch. The vernier scales provide a more accurate measurement.

Answer the following questions about scale:

1. How is scale defined? Answer: _____
2. For what purposes are architect's scales generally used? Answer: _____
3. What are the three guidelines for selecting a scale?

   Answer: a. _____
   b. _____
   c. _____

Answers:

1. It is the ratio of a drawn object to its actual size.
2. For construction drawings
3. a. Fit the paper
   b. Make it usable
   c. Make it appropriate to detail required

Dimensions

Dimensions complete the description or definition of size of a working drawing. Dimensions are indicated in inches, feet and inches, or decimals. The symbol for an inch is ″ while the symbol for a foot is ′. It is standard practice to place a hyphen between feet and inches if both units are used on a drawing. For example, nine and one-half feet would be expressed as 9′-6″. Usually if all measurements are in inches, the inch symbol is omitted, when the length exceeds 72″, foot dimensions and marks are used.

Frequently in manufacturing industries, the decimal system of dimensions is used. It provides for more exact control of manufactured parts. All figures on the drawing are shown as decimals. The standard convention is to measure and indicate two-place decimals to the right of the decimal point with the second number always being an even number—.16, .82, .74—rather than an odd number like, .67 or .05. The only exception to this convention occurs when greater precision in the part is required. In such instances, 3-place and 4-place dimensions are used. A fraction-decimal conversion chart is found in the Appendix of this booklet for your future reference.

Angle dimensions also are included on drawings. These dimensions are expressed in terms of degrees °, minutes ′ and seconds ″.

The size of an object is indicated by numbers placed within dimension lines on a drawing. Dimension lines are solid, light, thin lines terminated with arrowheads. They are located between extension lines and placed on the drawing in a way that avoids confusion. This means the lines usually are placed *beside* rather than *on* the illustration of the object. Extension lines do not touch the object but rather are light lines that extend from the view of the object and bound the dimensions. Arrowhead points of the dimension lines touch the extension lines.

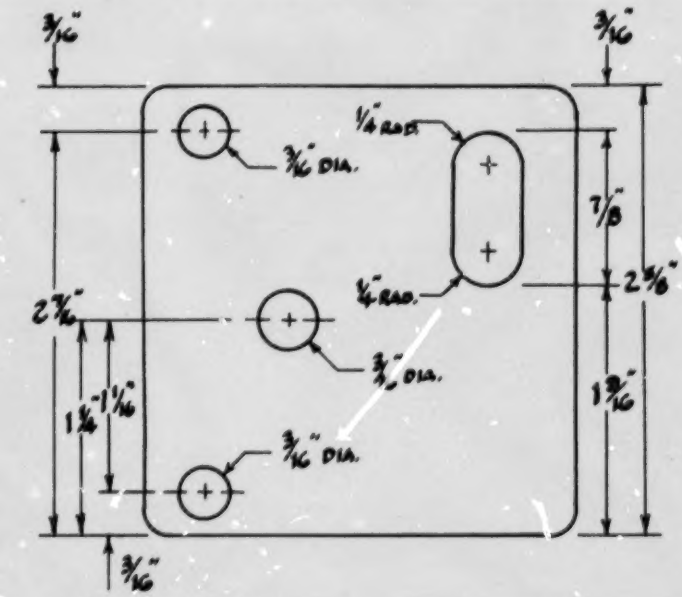
Stated as a set of general guidelines, the conventions for expressing dimensions as set forth by the American Standards Association are as follows:

1. Dimension lines are solid, light lines terminated by arrowheads.
2. Arrowhead points touch the edge of the extension lines and usually are but 1/2″ long.
3. The dimension line is broken by a space in which the measurement figure is written.
4. The figure should be no smaller than 1/8″, but can be larger.
5. On any single drawing, all figures should be the same size.
6. Dimension lines usually are placed at least 3/8″ from the object drawing.
7. Extension lines begin about 1/16″ from the object drawing.
8. Extension lines are drawn at right angles to the location on the drawing to which they apply.
9. Dimensions usually are placed so they can be read from the bottom.
10. Dimensions are grouped together and arranged so that they produce an orderly appearance.
11. Numerals are staggered, not less than 1/4″ apart so as to avoid confusion.
12. Fractions within dimensions usually are larger than whole numbers with each number about two-thirds the height of a whole number.
13. Do not repeat dimensions on the drawing.
14. Do not originate lines so that they will cross either extension or other dimension lines.
15. Do not originate or end dimensions on hidden lines.
16. The most important dimensions should be located with the principal or most important view of object.

Most of these guidelines are illustrated in Figure 7.

Dimensions provide information about both size and location. Length and width generally are the size directions. Location dimensions indicate where fasteners, holes, notches, arcs and so forth are located.

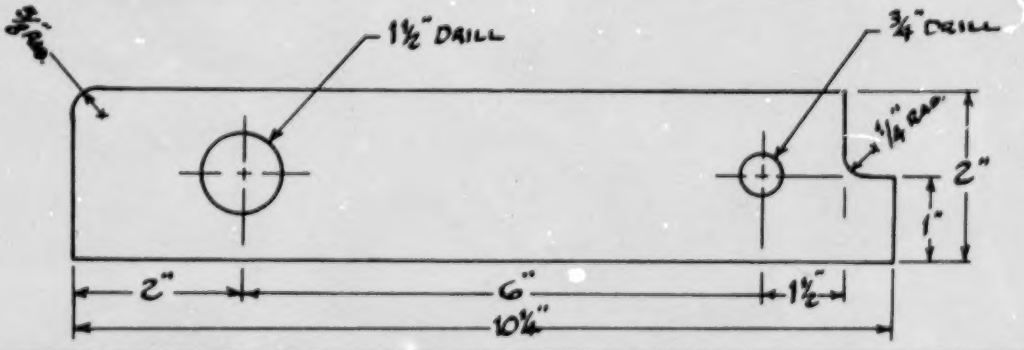
Figure 7. Guidelines for Dimensioning



Size and location dimensions frequently are used when working with circles, arcs, and angles. As with straight lines, a set of conventions applies to dimensioning these figures. For example, when drawing holes and circles, always locate the centers by means of a center line. Then, by extending the center line beyond the view of the object, use center lines in place of extension lines to indicate location. Do not use these to indicate size. Recall that a center line is a vertical and horizontal line drawn with a pattern of a long line, a space and a dash. Repeat the pattern to whatever length is necessary.

Always indicate the diameter of a circle or hole. You may indicate a radius for an arc, but use diameters for circles. Further, indicate diameters by using the letters DIA after the number; use an R after a radius figure. When indicating the diameter of a hole, point to the circle in question by drawing a line and arrow called a leader. Note that if the leader line were extended beyond the edge of the circle to which it refers, it would pass through the center of the circle. Figure 8 illustrates the points about dimensioning circles.

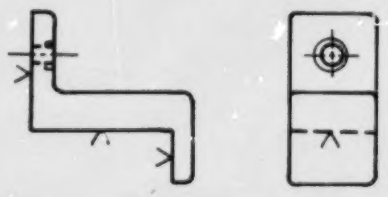
Figure 8. Circle Dimension Conventions



The information provided at the end of a leader on a circle dimension is called a note. Use notes to indicate number of pieces to be made, type of material to use, type of finish, or any other critical specifications, especially those for which there are not conventional symbols. Notes also can be used to indicate smaller or identical dimensions thus avoiding duplication on the drawing.

When notes are used, keep them brief and specific. Further, where possible, place them all together in a single location on the page, but not on a view of the drawing. A set of notes on a drawing of a metal collar to be made on a lathe might look like those presented in Figure 9. Notice that the notes have numbers, have a heading and are very brief.

Figure 9. Shop Notes

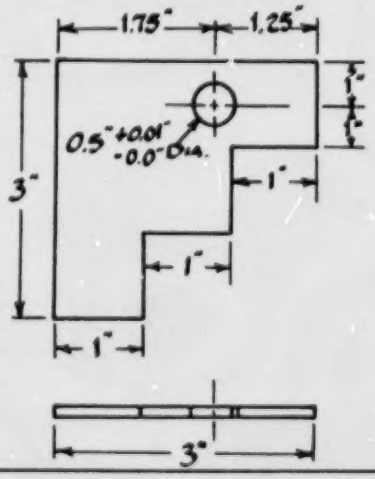


Note:
1. Drilled hole to be C'S'K 9/16" DIA. x 1/8" deep.
2. All finished surfaces require Type F finish.
3. Fillets and Rounds 1/8".

The allowable error in measurement is called the tolerance. It is the margin within which (above and/or below) a measurement can vary and still be accurate enough for use. Usually tolerances are expressed as decimals and are included on the drawing. The more important conventions surrounding tolerances are:

1. Specify tolerances in both the plus and minus directions. If these numbers are equal, they can be written and read as ±. If they are different, specify one number as plus and one number as minus.
2. If the numbers are different, place and read the high number above the low limit. If written in the notes, the low limit figure will precede the high one.
3. If the question of tolerance is not an issue, do not include it on a working drawing that you are constructing.

Figure 10. Tolerances

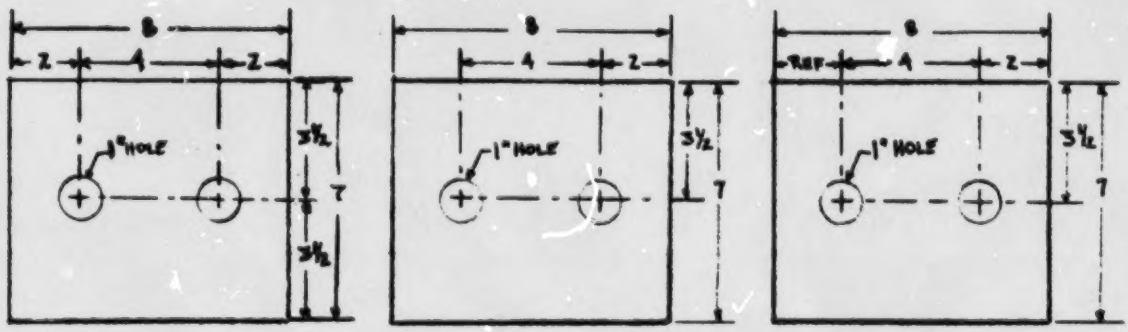


Note:
1. Finish all over to #4 finish.
2. Plate thickness is 0.25" ± 0.01".

Figure 10 illustrates the conventions for tolerances. Note that in one drawing the tolerance is included as a note while on the other, it is included in the dimensions.

Accuracy sometimes is addressed in other ways on working drawings. Refer, for example, to Figure 11. Note that none of the three drawings includes specified tolerances or decimals. This indicates that some tolerance for error exists. Drawing B has two dimensions omitted. This means that the overall dimensions must be held; if any error is to exist, it must be at the right side and on the top. Drawing C makes this even more clear by directing the worker to measure from the left to the right. The note "Ref." for reference means to measure from the other direction.

Figure 11. Measuring Tolerances



Acknowledging tolerances does not mean that inaccuracy is acceptable. Inaccuracy is wasteful and unacceptable. Tolerances simply allow for slight measurement error, due either to worker judgment or instrument problems.

Answer the following questions about dimensions:

1. Circle the letter of the dimension that probably is expressed incorrectly.
   A) 4 C) .32
   B) 6′ - 9″ D) 96″
2. What does the note ±2″ mean? Answer: _____

Answers:

1. = D
2. = That the measurement has a tolerance of +2″ to −2″

Additional Information

For additional information on dimensioning and scales, you may choose to read:

J. R. Linbeck and I. T. Lathrop. *General Industry, 2nd Edition.* Peoria, IL: Charles A. Bennet Co., 1977.

J. W. Giachino and J. J. Beukema. *Everyday Sketching and Drafting, 2nd Edition.* Chicago, IL: American Technical Society, 1973.

Self-test Exercises

Answer the following questions and compare your answers with those provided in the Appendix of this booklet.

1. What element of drawing does scale and dimension represent?

   Answer: _____

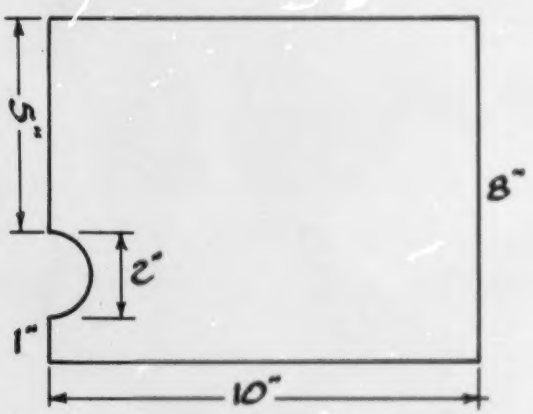
2. Why are some drawings made larger or smaller than actual size?

   Answer: _____

3. If you saw the dimension 5 on a figure, what would it mean?

   Answer: _____

4. Identify three rules of dimensioning which are violated in the following sketch?



   Answer: a. _____
   b. _____
   c. _____

5. Explain why tolerance is taken into account.

   Answer: _____

4. Types of Drawings

Chapter Overview

Purpose:	To insure that each apprentice recognizes and can interpret the various types of views in working drawings that frequently are encountered in the workplace.
Preassessment Score:	Write in the following space the number of correct answers from Pretest questions 10-13: _____. If you answered all 4 correctly, skip to Chapter 5. If you missed one or more questions, continue to work in this chapter.
Prerequisites:	Chapter 1, 2 and 3 of this booklet.
Resources:	Time—At least 30 minutes to completion. Materials—pencil
Performance Statement:	At the conclusion of this unit you will recognize, identify and explain the major characteristics of the types of working drawings used in work settings.
Performance Measure:	A fifteen-minute paper-and-pencil test to be taken after completing the entire booklet.
Standards:	To be successful, you must answer at least 70% of the Posttest items correctly.
Activities:	1. Read the text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the Self-test Exercises and Posttest.

Introduction and Objectives

Working drawings are made to be used. They provide sufficient information about an object to make, repair and/or use the object. They are absolutely essential for construction of almost any product. Working drawings provide necessary information about:

- Size and shape of object
- Location of component parts and features
- Materials specifications
- Fasteners, hardware, adhesives, and other custom fasteners
- Finishing techniques and sometimes instructions

As indicated in Chapter 3, the first two items noted above usually are provided by the dimensions, while the latter three items are included as notes. It is with the size, shape and location of component parts as presented visually to the worker in drawings that this chapter is concerned. More specifically, as a journeyman you must recognize and interpret each of the various types of working drawings. Each has specific uses, advantages and methods. When you have completed your work in this chapter, you will demonstrate your understanding of working drawings by being able to:

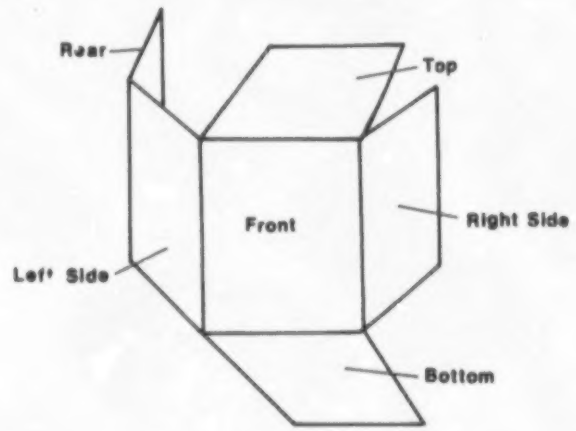
1. Recognize and identify the different types and elements of working drawings, and
2. Interpret, explain and critique examples of various types of working drawings.

Principles, Examples and Applications

Orthographic Projection

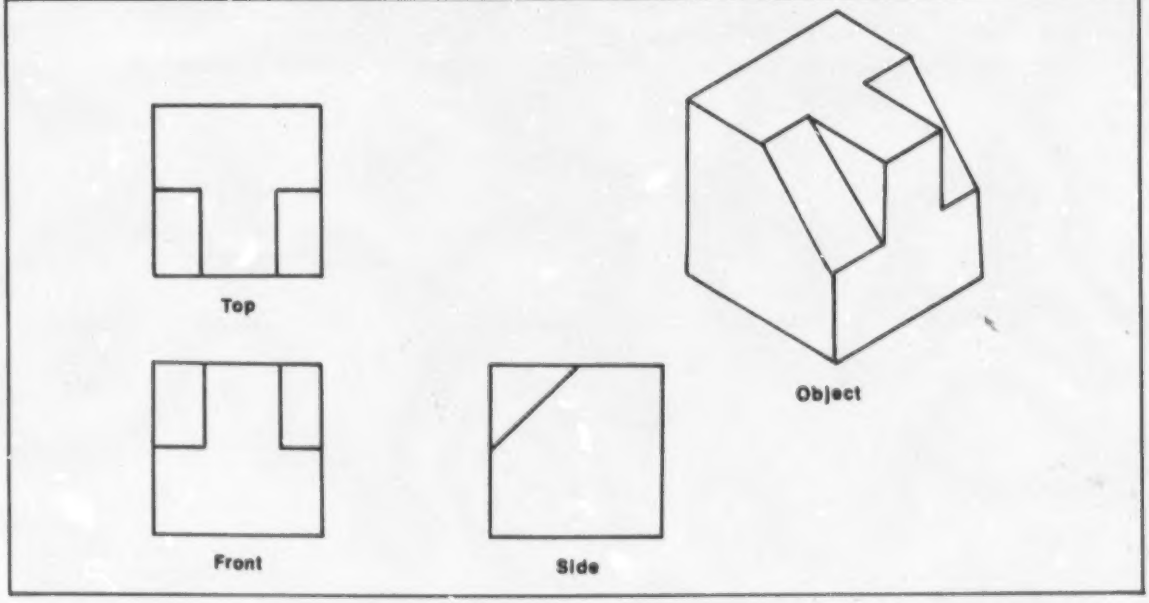
Working drawings must show a great deal of detail and information. Therefore, actual pictures usually are not suitable. They are too cluttered and confusing. Instead, the most frequently used type of drawing is the orthographic projection. The orthographic projection is a multiview drawing of an object where each view is at right angles to every other view. The views are projected on flat surfaces and do not show perspective.

Figure 12. Planes in an Orthographic Projection



To illustrate what an orthographic projection is, imagine an object like a machine part or cabinet in a clear plastic box. Further, imagine that each side of the plastic box is on hinges so that it opens out flat on a surface as illustrated in Figure 12. Now, looking straight into each side, including top and bottom, of the box, imagine that you trace the outline of the object in the box on the plastic surfaces. Then you open the box out flat on a surface. Notice that the box and object within the box has six views: top, bottom, front, back, left side and right side. Each side is a possible view to include in an orthographic projection. However, most orthographic projections show only three of the six views—front, top and right side. The front is usually the most critical. However, you should select the three views that offer the best description of the object in question and show the object in its natural position. Figure 13 is an example of an orthographic projection.

Figure 13. Orthographic Projection

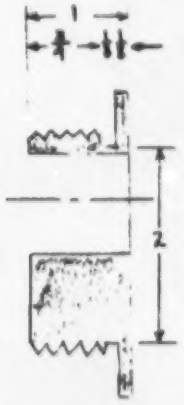


As you examine Figure 13, note that some objects do not require three views in a complete orthographic projection. For example, a map or a sphere requires only one view to be complete. A cylinder requires two views to be complete.

Sectional Views

Sometimes sectional and auxiliary views are necessary to make a drawing clear or useful. For example, complicated multi-level circuitry or complex parts would be difficult to build without knowing what the object looked like on the inside. Sectional views are made by "cutting" or slicing the object in two and removing the front half. The drawing illustrates the remaining half of the object, from the inside out. Auxiliary views show only the principal elements of the orthographic projection of front, top and right side, but are drawn to true size and shape rather than scale. Figure 14 illustrates a sectional view.

Figure 14. Sample Sectional View



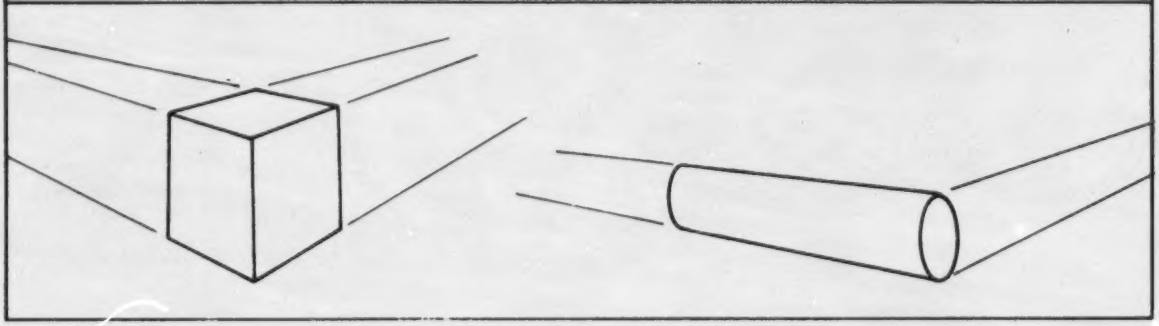
Pictorial Drawings

Pictorial drawings are drawings that are drawn as they appear to your eye. Three types of pictorial drawings are used in apprenticeable trades: (1) perspective, (2) isometric and (3) oblique.

Perspective Drawing

The perspective drawing is the most realistic of the three types of pictorial drawings. It is based on the fact that objects appear smaller the farther away they are from you as the observer. Eventually, if the object is long enough—like a highway, fence or railroad track, the object disappears at the horizon. The point where it disappears is called the vanishing point. Figure 15 illustrates a perspective drawing with an extrapolated vanishing point.

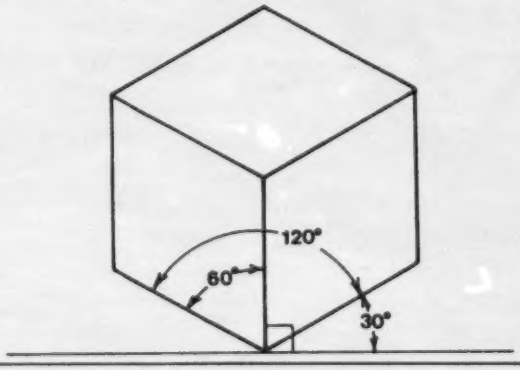
Figure 15. Sample Perspective Drawings



Isometric Drawing

Isometric drawings show three surfaces of the selected object, each on a different axis. One axis is vertical; the other two are drawn to the right and left at an angle of 30° to the horizontal so that the object can be rotated right or left about the vertical axis. Circles drawn in the isometric form are ellipses. Figure 16 illustrates an isometric drawing and the two axes of an isometric drawing.

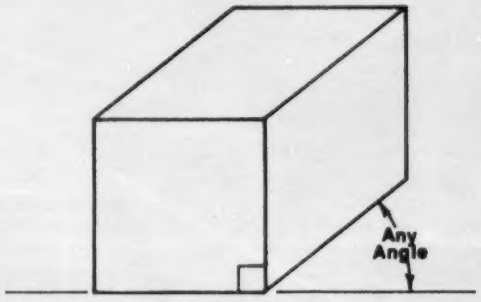
Figure 16. Isometric Drawing



Oblique Drawings

Oblique drawings also have three axes. Unlike the isometric drawing, oblique drawings are made from the front view with the top and right side views attached and lying either at angles of 30° or 45° with the front view. The advantage of the oblique drawing is that the front view is the true shape of the object. The side and top views are slightly elongated. Figure 17 illustrates an oblique drawing.

Figure 17. Oblique Drawing



Additional Information

For additional information about types of drawings and views, you may wish to read:

J. R. Lindbeck and I. T. Lathrop. *General Industry, 2nd Edition.* Peoria, IL: Charles A. Bennet Co., Inc., 1977.

J. W. Fleming, D. F. Barock and L. C. Smith. *Applied Drawing and Sketching.* Chicago, IL: American Technical Society, 1950.

Self-test Exercise

Answer the following questions and check your answers with those provided in the Appendix.

1. What is the primary factor to consider when deciding which views to show in an orthographic projection?

   Answer: _____

2. What views are typically shown in an orthographic projection?

   Answer: _____

3. In terms of views discussed, the oblique drawing differs from the isometric drawing in what major ways?

   Answer: _____

5. Sketching

Chapter Overview

Purpose:	To insure that each apprentice has the skill and knowledge to communicate through rough sketches.
Preassessment Score:	Regardless of your score, work through this chapter.
Prerequisites:	Chapter 1, 2, 3 and 4 of this booklet.
Resources:	Time—At least 30 minutes to completion. Materials—pencil, paper.
Performance Statement:	At the conclusion of this unit you will explain and demonstrate the principal techniques associated with sketching lines and objects.
Performance Measure:	A fifteen-minute paper-and-pencil test to be taken after completing the entire booklet.
Standards:	To be successful, you must answer at least 70% of all Posttest items correctly.
Activities:	1. Read the text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the Self-test Exercises and Posttest.

Introduction and Objectives

On the job, sketches made by supervisors, foremen and journeymen frequently are more useful than either verbal explanations of how to do something or the formal drawings that illustrate the product or process. Sketches can be used to highlight certain features of products or processes such as particularly difficult portions of the product or process or the part of the product or process on which people currently are working. In both instances, the sketch defines clearly the technical information under consideration and explains the specifics of complicated parts or relationships.

As a skill, sketching is valuable to journeymen for several reasons. First, often you will be able to explain and describe an idea, process, or product to other workers by using a sketch. In this type of situation, a picture is worth pages and pages of words. Second, because sketches are quick, easy and focused on particular aspects of products or processes, they are easier to use and frequently more efficient than are formal drawings. Third, by learning to sketch, you will become a

better observer, especially of detail and relationships of parts-to-the-whole. Improved observation results in increased quality of workmanship and increased self-confidence.

This chapter presents the practice of sketching. When you have completed your work in this unit, you will demonstrate your competence with the information in the chapter by:

1. Identifying accepted techniques and practices for sketching; and
2. Demonstrating your sketching proficiency with job-related subjects.

Principles, Examples and Applications

Sketching Tools and Materials

Sketching tools are simple. All you need is a pencil, an eraser, and paper. In general, use a soft pencil like a #2 for on-the-job sketching. Harder leads can be used when additional accuracy is required. Do not use ballpoint pens because ink lines are difficult to correct if you make a mistake or change your mind.

Paper must be tough enough to endure erasing. Often graph paper or paper covered with some kind of grid or lines will help you to draw dimensions.

Steps and Procedures in the Sketching Process

Sketching is a help to describe and explain products, processes, and ideas. Rarely are sketches drawn to any scale. However, you should try to maintain some degree of proportion throughout the sketch. The degree of accuracy and detail should be determined by the use of the drawing. Remember, the beauty of a sketch is both speed and accuracy.

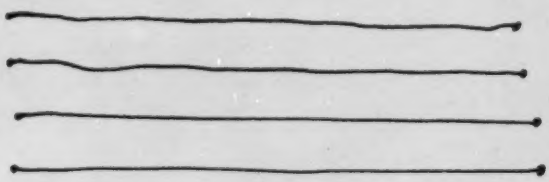
There are no rules about holding your pencil. Hold it however it is easiest and most comfortable for you. All you must do is draw lines.

Drawing Lines

The type and quality of the line you draw is determined by your control of the movement of your wrist, fingers, shoulder and elbow. Use arm movement rather than finger and wrist movement to draw smooth lines. Regulate line heaviness by changing the amount of pressure on the pencil. Draw straight lines between two points. Use one point as a starting point and the other point as a guide to which you draw. The line connects the dots with a quick, easy stroke. Keep your eye on the "guide" point. Avoid jerky, wiggly, wavy lines. Usually wiggly lines mean that either you are using too much finger or wrist movement rather than shoulder or elbow movement or that you drew the line too slowly.

Practice drawing lines on your paper. First place 9 dots on the left side of the sheet. Next, place 9 corresponding dots on the right side of the paper. Now draw two or three wiggly lines left to right across the paper using the top three sets of dots on each side. Now, using the next three sets of dots, draw three more lines, left to right on the papers. This second set of three lines should be drawn more tightly or less wiggly than the first set. Next, using the last three sets of dots, quickly draw straight lines between sets of dots. When you have finished, your paper should look like Figure 18.

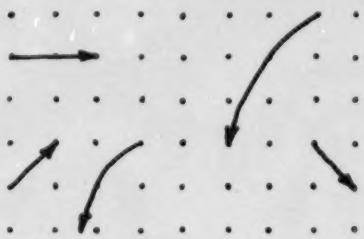
Figure 18. Lines



The key to good, straight lines is free arm and elbow movement. Usually it is a good idea to practice the motion of the stroke without touching the pencil to paper. After several practices, draw the line. Practice and freedom of movement result in drawing straight lines.

Using Figure 19, draw the lines indicated on the illustration. Notice that, for righthanded people, the arrow on the sample indicates the preferred direction of the pencil stroke.

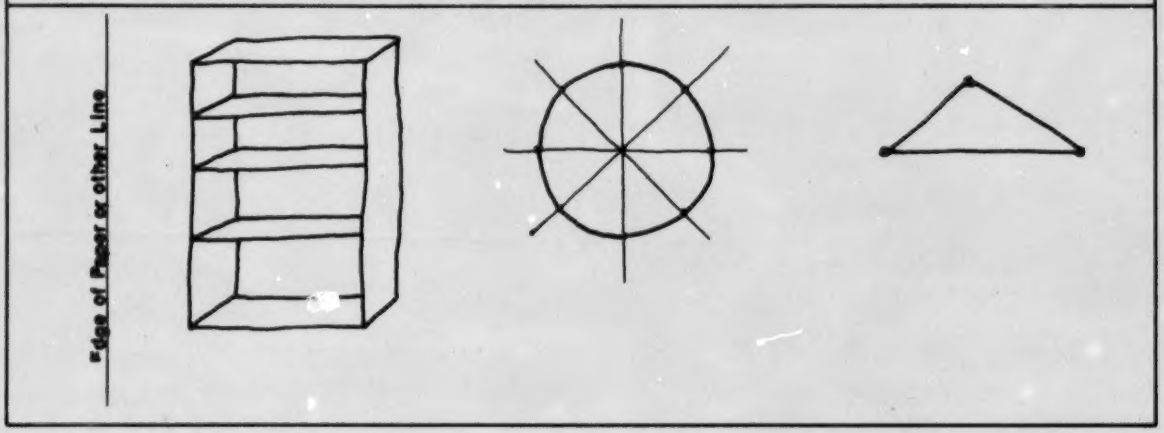
Figure 19. Line Practice



Sketching Objects

Once you have mastered drawing lines, drawing sketches becomes a relatively easy task of connecting various lines to form shapes. The basic procedures are: (1) consider the overall dimensions of the object you will draw and imagine what it will look like on the paper as a way to help work out the proportions; and (2) use a series of dots or guidelines to help you get both basic shape and detail through connecting dots. For example, if you are sketching a bookcase or a piece of paper as illustrated in Figure 20, you could use the borders of the paper and a series of dots to draw right angles. Even circles and triangles are drawn most easily if they are first laid out with points and intersecting lines marking the center and perimeter. Circles and arcs also can be drawn by rotating the paper around your little finger of your pencil hand at the circle's center point while holding the pencil firmly on the paper with your thumb and index finger. Examples of use of dots and interesecting lines as guides is illustrated in Figure 20.

Figure 20. Use of Guidelines and Dots



Additional Information

For additional information about types of drawings and views, you may wish to read:

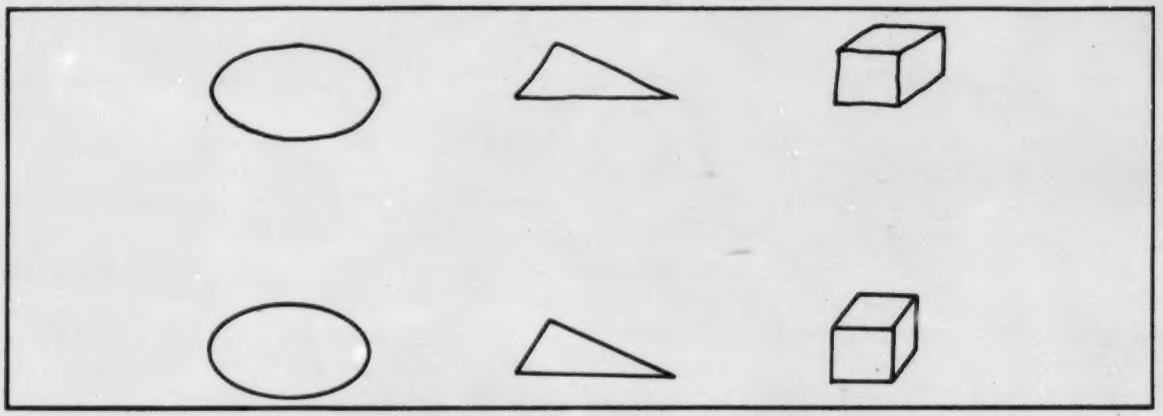
R. S. Oliver. *The Sketch.* New York: Van Nostrand Reinhold Co., 1979.

J. W. Giachino and H. J. Beukeua. *Freehand Sketching.* Chicago, IL: American Technical Society, 1973.

Self-test Exercises

Answer each of the following questions and compare your answers with those provided in the Appendix of this booklet.

1. Drawing firm, clear lines in sketches usually requires freedom of movement of what parts of the body? Answer: _____
2. Wiggly lines usually indicate what problems with drawing lines?
   Answer: _____ and _____
3. Draw the figures suggested in the following space:



6. Reading Blueprints

Chapter Overview

Purpose:	To provide each apprentice with practice in reading shop, assembly and construction drawings and blueprints.
Preassessment Score:	Regardless of your Pretest score, review the content in this chapter.
Prerequisites:	Chapter 1, 2, 3, 4 and 5 of this booklet.
Resources:	Time—At least 30 minutes to completion. Materials—pencil
Performance Statement:	At the conclusion of your work in this chapter you will be more comfortable with and conversant in reading blueprints and working drawings.
Performance Measure:	A fifteen-minute paper-and-pencil test to be taken after completing the entire booklet.
Standards:	To be successful, you must answer at least 70% of the Posttest items correctly.
Activities:	1. Read the text, examples and illustrations and commit information to memory. 2. Work questions, examples and problems. 3. Complete and check the Self-test Exercises and Posttest.

Introduction and Objectives

Every journeyman must read and use blueprints and working drawings. The skills required to do this are acquired through careful study of blueprints and drawings coupled with the actual use of such materials on the job. In most apprenticeship programs you will study intensively sample blueprints drawn specifically for your trade. The materials in this chapter serve either as an introduction to such study or a refresher about prior learning concerning reading blueprints and working drawings. When you have completed your work in this unit you will demonstrate your competence by being able to:

1. Identify terms and symbols commonly used on manufacturing and construction blueprints; and
2. Interpret and describe sample blueprints and working drawings.

Principles, Examples and Applications

Assembly Drawings and Machine Shop Drawings

Assembly drawings and machine shop drawings must contain all the information necessary to make and assemble parts and products. Each part has its own detail drawing; an assembly drawing then illustrates how the various parts fit together.

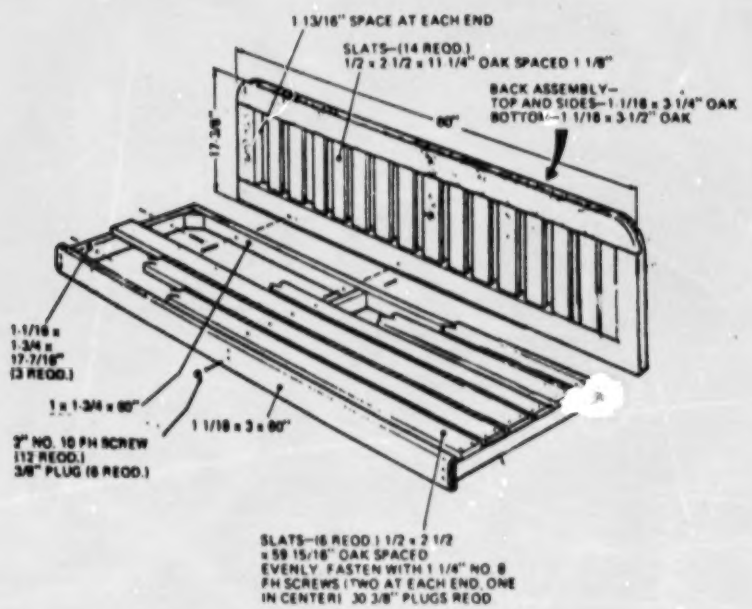
Examine the drawing in Figure 21. This is a sample assembly drawing. Answer the following questions about the drawing:

1. What is the spacing between the oak slats and the back of the swing?
   Answer: _____
2. How many 2" number 12 screws are required? Answer: _____
3. What is the length of the swing? Answer: _____
4. What total length (in linear feet) of 1/2" x 2 1/2" oak board is required?
   Answer: _____

Answers:

1. = 1-1/8"
2. = 7
3. = 60" or 5'
4. = Approximately 21'1" or 253"

Figure 21. Example of Assembly Drawing


1 13/16" SPACE AT EACH END
SLATS—(14 REQD.)
1/2 x 2 1/2 x 11 1/4" OAK SPACED 1 1/8"
BACK ASSEMBLY—
TOP AND SIDES—1 1/16 x 3 1/4" OAK
BOTTOM—1 1/16 x 3 1/2" OAK
17 3/8"
60"
1-1/16 x
1-3/4 x
17-7/16"
(3 REQD.)
1 x 1-3/4 x 60"
1 1/16 x 3 x 60"
2" NO. 10 FH SCREW
(12 REQD.)
3/8" PLUG (6 REQD.)
SLATS—16 REQD.) 1/2 x 2 1/2
x 59 15/16" OAK SPACED
EVENLY FASTEN WITH 1 1/4" NO. 8
FH SCREWS (TWO AT EACH END, ONE
IN CENTER) 30 3/8" PLUGS REQD

Adapted from *Popular Mechanics*, May 1978.

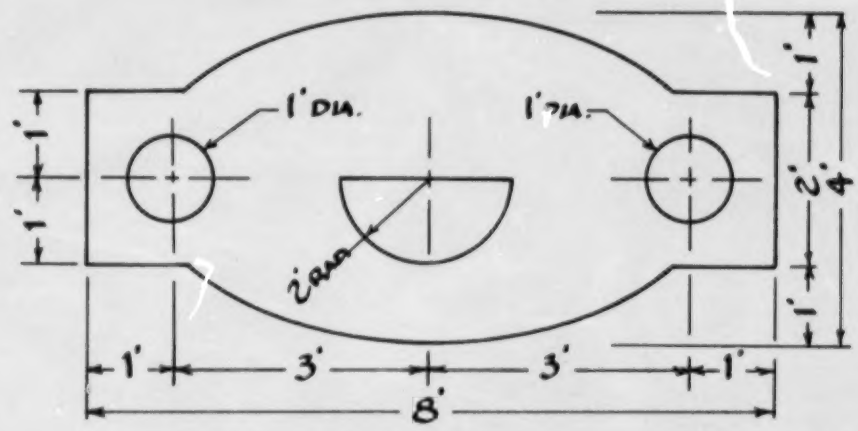
Examine the drawing in Figure 22. This is a sample machine shop drawing. Answer the following questions about the drawing:

1. What is the radius of the circular holes? Answer: _____
2. How far is the closer edge of the circular hole to the semicircle in the middle? Answer: _____

Answers:

1. = 6"R
2. = 6"

Figure 22. Sample Machine Shop Drawing



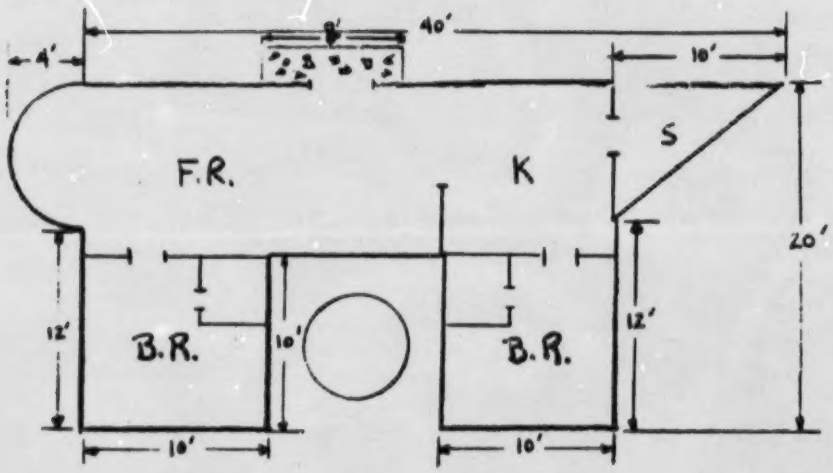
You have noticed that several abbreviations are used on the drawings. The more commonly used abbreviations on shop and working drawings include:

Blueprint	B/P	Centerline	℄	Head	HD	Screw	SCR
Brass	BR	Centerbore	C'BORE	Inside	I.D.	Snug Fit	SN.F.
Bronze	BZ	Centersink	C'SINK	diameter		Standard	STD
Cast Iron	C.I.	Diameter	DIA	Material	MAT	Steel	ST
Cast Steel	C.S.	Finish	f	Pound	#	Thread	THD
				Radius	R		

Construction Drawings and Blueprints

Construction drawings and blueprints contain all the information necessary to build the structure in the drawing. The important things about reading construction blueprints are first to visualize the shape of the structure being built and second to learn and use the conventions or symbols on the blueprint. Figure 23 is a sample of part of a construction blueprint. Study the drawing and answer the following questions.

Figure 23. Sample Construction Blueprint



1. What are the dimensions of the family room? Answer: _____
2. What is the width of the house at its widest point? Answer: _____
3. From what substance is the porch constructed? Answer: _____

Answers:

1. = 10' x 34'
2. = 20'
3. = concrete

As with shop blueprints, construction blueprints often contain specialized terms and abbreviations that you must memorize. Among the more common terms and abbreviations are:

Angles	<s	Double Strength Glass	D.S.A.	Linoleum	LINOL
Beam	B'M			Living Room	L.R.
Bedroom	B.R.	Frame	FRM	Mortar	MOR
Center to Center	C.to C.	Gas Range	G.R.	Recessed	REC.
		Hall	H	Standard Door	S.D.
Closet	Clos. or CL.	Joist Space	J.S.	Water Closet	W.C.
		Kitchen	K	Wrought Iron	W.I.
Conduit	COND.	Kitchen Cabinet	K.C.	Yellow Pine	Y.P.
Detail	DET.	Lavatory	LAV.		

Additional Information

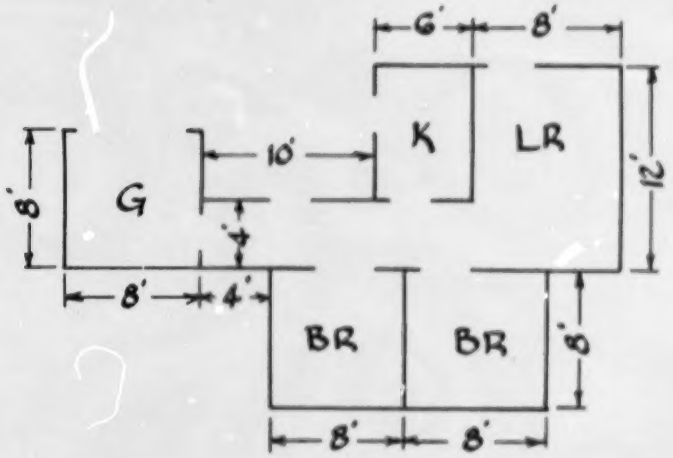
For additional information about reading blueprints, see either the specific trade training materials for your trade or:
E. W. Sundberg. *Building Trades Blueprint Reading.* Chicago, IL: American Technical Society, 1972.

Self-test Exercises

Answer the following questions and check your answers with those provided in the Appendix.

1. What do each of the following abbreviations mean?
   a. COND _____ d. D.S.A. _____ g. REC. _____
   b. B/P _____ e. ⊄s _____ h. L.R. _____
   c. C'SINK _____ f. DIA _____ i. # _____

2. Examine the following drawing. What are the dimensions of the kitchen?



Answer: _____

3. What is the area in square feet of the living room? Answer: _____

7. Appendix

Answers to Pretest

1. Hidden edge
2. Dimension and Extension
3. a
4. d
5. To illustrate large distances
6. The ratio of a drawn object to its actual size.
7. Size and location
8. The diameter of the hole is .5 inches, plus or minus one one thousandth of an inch.
9. b
10. All five items should be checked
11. b
12. c
13. d

Answers to Self-test Exercises

Chapter 2: Lines, Symbols and Lettering

1. a. = 3, b. = 1; c. = 2
2. a. = 4; b. = 2; c. = 1; d. = 3
3. A E G

Chapter 3: Scales and Dimensions

1. Size of object
2. To fit on page; to provide sufficient detail; to show interrelated parts.
3. Five inches
4. Many rules have been violated including:
   a. All dimensions must be read from same side.
   b. Do not write on drawing.
   c. Use extension and dimension lines.
   d. Be consistent in using feet and inches.
5. To account for small errors in tools or in human use.

Chapter 4: Types of Drawings

1. The selected view must provide the best description.
2. Front, Top and Right Side
3. Oblique drawings have a front view that shows true size and is presented face-on to the viewer whereas an isometric drawing is presented to the viewer at about a 30' angle.

Chapter 5: Sketching

1. Shoulder, elbow and arm
2. Either the line was drawn too slowly or with too much use of fingers and wrists.

Chapter 6: Reading Blueprints

1. a. Conduit
   b. Blueprint
   c. Countersink
   d. Double strength glass
   e. Angles
   f. Diameter
   g. Recessed
   h. Living room
   i. Pound
2. 7' x 8' or 56 square feet
3. 112 square feet

Posttest

Directions: Answer the following questions and check your answers. If you score at least 70 percent, continue your work in the next booklet. If you score less than 70 percent, repeat the portions of this booklet with which you had difficulty.

1. Dimension provides information about what elements of design?

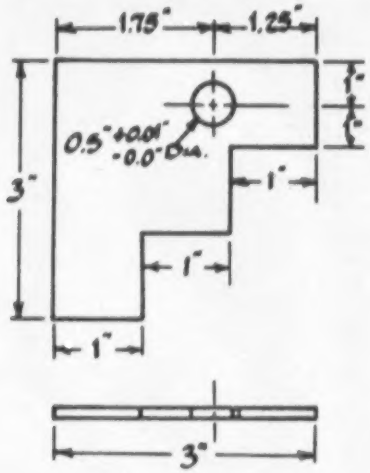
   Answer: _____

2. What does the following type of line mean?

   ——— - ——— - ———

   Answer: _____

3. What does the following dimension mean for tolerance of the hole?



   Answer: _____

4. Why are some drawings of some objects made larger or smaller than the actual object?

   Answer: _____

5. Most orthographic projections provide three views. What are they?

   Answer: _____

6. Wiggly lines in drawings usually indicate what types of problems?

   Answer: _____

7. What do the following abbreviations mean?

   a. DIA _____ b. I.D. _____

8. (from pretest)

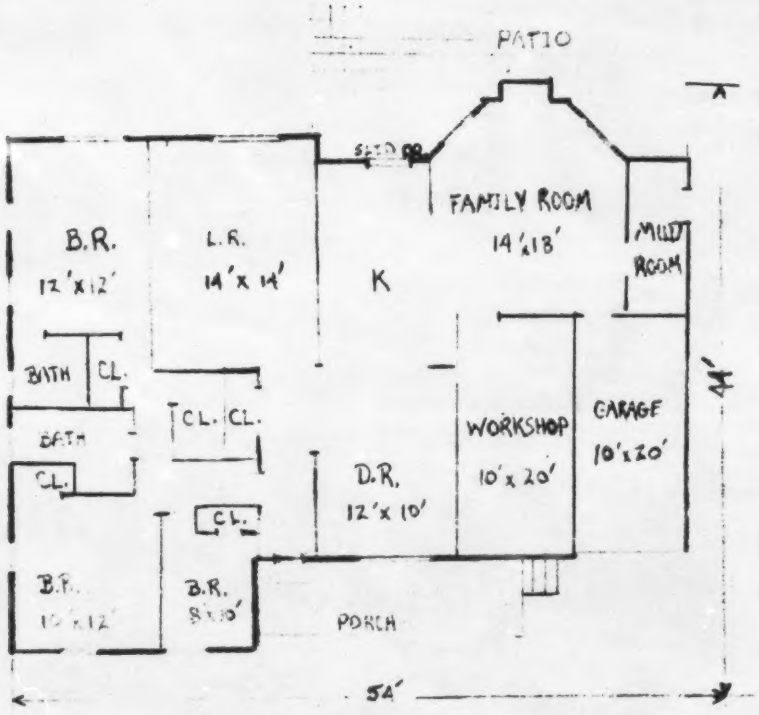
Look at the following diagram and answer questions 9 and 10.

9. **What is the total square footage of bedroom floor space, including closets, for the house?**

   Answer: _____

10. **What are the dimensions of the garage?**

    Answer: _____



Posttest Answers

1. Size and location
2. Center line
3. Tolerance can be 0.01 longer, but 0.0 smaller than 0.5" DIA.
4. To fit on page, provide sufficient detail; to show interrelated parts.
5. Front, top and right side.
6. Either the line was drawn too slowly or with too much use of fingers and wrists.
7. a. Diameter b. Inside diameter
8. b .
9. 354 sq. feet.
10. 10' x 20 '

Scoring

Each question counts 1 point. You must answer at least 7 questions correctly to complete your work in this booklet.